IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF OKLAHOMA

STATE OF OKLAHOMA,	)	
	)	
Plaintiff,	)	
	)	
v.	)	**Case No. 05-cv-329-GKF(PJC)**
	)	
TYSON FOODS, INC., et al.,	)	
	)	
Defendants.	)	

DECLARATION OF BERNARD ENGEL, Ph.D.

I, Bernard Engel, Ph.D., hereby declare as follows:

A. BACKGROUND

1.

I hold a B.S. and M.S. in Agricultural and Biological Engineering from the University of Illinois and a Ph.D. in Agricultural Engineering from Purdue University. I am a registered professional engineer in the State of Indiana. Since 1988, I have been a faculty member in the Purdue University Department of Agricultural and Biological Engineering. I am currently Department Head and Professor within this program. My research, teaching and outreach expertise are in environmental engineering and the application of information systems technologies to environmental problems. I have extensive experience in developing and applying computer models, databases, and geographic information systems to a range of environmental issues. In this regard, I have developed hydrologic/water quality models and decision support systems that are widely used by consultants and local, state and federal agencies. My work has allowed me to obtain extensive experience in applying models and information technologies to assess nutrient and pesticide movement in surface waters of watersheds and into watershed

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groundwater. I have published more than 100 articles on related topics in peer reviewed scientific journals.

2.

I have been retained by the Oklahoma Attorney General to evaluate the generation and land application of poultry waste within the Illinois River Watershed ("IRW"). In addition, I have been asked to evaluate the movement of this waste and its constituents into streams, rivers, and groundwater within the IRW and into Lake Tenkiller.

B. EXPERT REPORT

3.

On May 22, 2008, I submitted an Expert Report to the Defendants in the above-captioned litigation (attached hereto as Ex. 1). This Expert Report contains statements, findings, analyses and opinions related to my evaluation of the generation and land application of poultry waste within the IRW and the movement of this waste and its constituents into streams, rivers, and groundwater within the IRW and into Lake Tenkiller.

4.

The following excerpts from my Expert Report consist of true and correct statements, findings, analyses and opinions:

5.

> "Elevated soil P from poultry waste application to pasture can also contribute substantially to P losses in runoff. Figures 8.2 and 8.3 show the results of a study in which poultry litter was applied to Bermuda grass plots (Sharpley et al., 2007). The soil P levels increased, resulting in greatly increased surface runoff of P, even

6 years after litter application was stopped. For high levels of STP, P loss with runoff may occur for decades and beyond…."

Surface soil (0 to 5 cm) Mehlich-3 P and mean annual dissolved P concentration of surface runoff and subsurface flow (70 cm depth) from bermudagrass before, during, and after poultry litter application (11 Mg ha⁻¹ yr⁻¹; 140 kg P ha⁻¹ yr⁻¹).

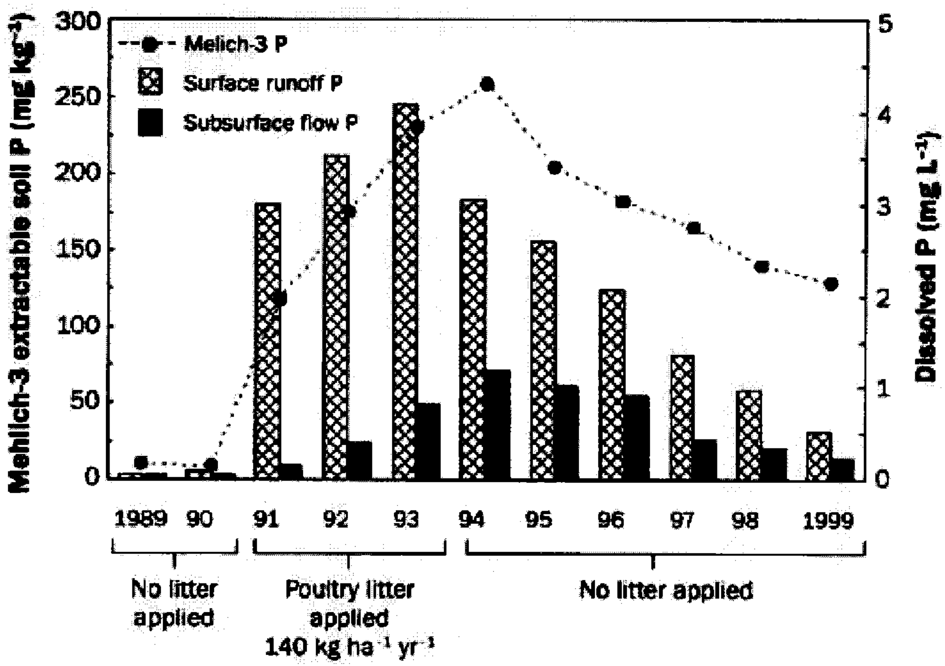

Figure 8.2. P Loads in Runoff Due to Elevated Soil P Levels (From Sharpley et al. (2007))

Phosphorus budget of poultry litter application, phosphorus uptake by bermudagrass, and total phosphorus loss in surface and subsurface flow from a Ruston fine sandy loam in Oklahoma.

		Bermudagrass		Total P loss in flow		
Year	Litter P added (kg ha⁻¹ yr⁻¹)	Yield (kg ha⁻¹ yr⁻¹)	P uptake (kg ha⁻¹ yr⁻¹)	Surface (kg ha⁻¹ yr⁻¹)	Subsurface (kg ha⁻¹ yr⁻¹)	P balance
Before application						
1989	0	3,500	5.9	0.2	0.1	-6.2
1990	0	4,010	6.4	0.2	0.1	-6.7
During application						
1991	140	8,110	16.9	3.8	0.1	+119.2
1992	140	8,210	18.6	5.1	0.4	+115.9
1993	140	8,510	20.0	7.8	0.5	+111.7
After application						
1994	0	8,040	22.5	5.6	0.7	-28.8
1995	0	7,120	18.2	4.2	0.6	-23.0
1994	0	6,920	15.2	2.2	0.5	-15.9
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1999	0	6,900	17.4	0.9	0.2	-18.5
Total	420	76,060	179.0	32.9	3.8	+206.0

Notes: Balance of P was determined as litter P added - P uptake by grass +P loss in surface runoff + P loss in subsurface flow. Negative values indicate a net loss of P from the plots and positive values a net gain of P.

Figure 8.3. P Loads in Runoff Due to Elevated Soil P Levels (From Sharpley et al. (2007))"

(Expert Report, Ex.1 at 38-39)

6.

"...Phosphorus Mass Balance

The movement of phosphorus into and out of an area (e.g., a mass balance analysis) provides insight into the primary sources of P within an area such as a watershed. ***A P mass balance for the Illinois River Watershed indicates poultry production is a substantial contributor to P within the Illinois River Watershed. Poultry production within the Illinois River Watershed is currently responsible for more than 76% of P movement into the watershed.***

...P Mass Balance Analysis for the IRW

Under my direction, M. Smith performed of an analysis that examined the flow of P into and out of the IRW system (e.g., a mass balance) (see Appendix B for full analysis). The findings include:

1. Poultry production is currently responsible for more than 76% of the net annual phosphorus additions to the IRW.

2. Historical data indicates poultry production has been the major contributor of phosphorus to the watershed since 1964. Prior to 1964, dairy cattle were responsible for the majority of the phosphorus contribution.

3. From 1949 to 2002, there was more than 219,000 tons of phosphorus added to the IRW. Almost 68% of that addition, more than 148,000 tons, was attributable to poultry production.

4. Other contributing sources of phosphorus (net additions) include commercial fertilizers (7.5%), dairy cattle (5.2%), humans (3.2%), swine (2.9%), industrial sources – mostly poultry processing facilities (2.7%) and beef cattle (1.7%). The remaining sources of phosphorus evaluated in this study, which include urban runoff, golf courses, wholesale nurseries, and recreational users, are negligible (< 1%).

5. Of the three phosphorus exports from the watershed (harvested crops, harvested deer, and water leaving Lake Tenkiller through the spillway) outflow of phosphorus through the spillway at the south end of Lake Tenkiller was the largest. According to current estimates, the flow of water through the spillway removes just under 1.25% of the total annual phosphorus additions to the watershed. The remaining two phosphorus exports combined remove just over

0.25% of current annual phosphorus additions to the watershed, totaling a 1.5% removal of current phosphorus additions."

P Mass Balance Literature

The scientific literature describes similar approaches as that used by the mass balance analysis set forth in Appendix B. In addition, some of these studies include portions of the IRW and reached similar conclusions as those highlighted above and in Appendix B.

Slaton et al. (2004) indicate that a fundamental component of nutrient management strategies is to determine the balance between nutrient inputs and outputs to identify areas where soil nutrient inputs are greater than removals. Slaton et al. (2004) termed such areas as "critical areas" and indicated that nationally many such areas have been identified and these areas coincide with concentrated animal production. They identified critical nutrient areas within Arkansas by dividing Arkansas into 9 geographic regions and computing a nutrient mass balance for each region. Nutrient removal by crops and nutrient inputs from livestock production were computed based on Agricultural Statistics Service data. Livestock nutrient inputs to soils were computed based on livestock numbers and nutrient content of livestock waste by species. Nutrients contained in beef cattle manure were ignored by Slaton et al. (2004) as they indicate "a large proportion of these nutrients are obtained from forage and deposited directly (i.e., recycled) to pastures during grazing rather than collected in lagoons or stockpiled from confined animal production facilities." Nutrient inputs from inorganic fertilizers were computed based on Arkansas fertilizer sales data.

Slaton et al. (2004) found that the district with the greatest excess N and P was northwest Arkansas which includes Benton and Washington counties. This region was estimated to have an accumulated P in soils for a 5 year period of 32 kg/ha. Kellogg et al. (2000) and Kellogg (2001) conducted a national nutrient balance assessment and identified the Illinois River Watershed and the northwest Arkansas and northeast Oklahoma area as being vulnerable to P loss in runoff due to excess manure based P being land applied. Sharpley et al. (2007) indicate that the spatial separation of crop and poultry production systems results in a large-scale one-way transfer of nutrients from grain to poultry producing areas. This is certainly the case for the IRW.

A similar mass balance approach was used by Mallin and Cahoon (2003) to estimate nutrients in livestock waste within North Carolina. Stow et al. (2001) also used a similar approach in computing nutrient inputs into the Neuse River Watershed in North Carolina. Cassell et al. (2002) used a mass balance and modeling approach in exploring P losses from watersheds. Sharpley et al. (2007) computed P surpluses for farms and found that poultry farms had the greatest P surpluses. Tarkalson and Mikkelsen (2003) examined P surpluses on a typical poultry farm and found that an annual surplus of 65 kg P per ha was available for broiler farms and indicated this presents a potential hazard to surface water quality.

The accumulation of excess P in soils is problematic, since soil P levels are correlated to the amount of P in runoff (Slaton et al., 2004). One of the solutions to this problem is the transportation of manure outside the critical watersheds with substantial animal production to row-crop production areas (Slaton et al., 2004). However, they indicate that "the low economic value of poultry litter, which represents the majority of organic nutrient sources produced in Arkansas, as a fertilizer nutrient source is believed to prohibit its transport to the primary rowcrop production area." Slaton et al. (2004) conclude that their assessment may help reinforce the thought that current nutrient application strategies in western Arkansas are not sustainable without the danger of creating and/or exacerbating water quality issues from excessive nutrients.

Nelson et al. (2002) performed a phosphorus mass balance for the Arkansas portion of the Illinois River Watershed. Sources of P identified in the mass balance were livestock manure, inorganic fertilizers, sludge applications and point source inputs from wastewater treatment plants. Livestock production was estimated based on agricultural statistics by county and the portion of these livestock within the watershed was allocated based on land use (pasture). A reference value of P excreted by livestock was used with the livestock production numbers to estimate total P by livestock species. Nelson et al. (2002) included dairy and beef cattle in the mass balance calculations but indicated that "beef and dairy are the only animals that obtain the majority of their phosphorus through grazing. Therefore, they are consuming plant phosphorus and depositing manure phosphorus (i.e., no net change in phosphorus in IRDA (Illinois River Drainage Area))." A presentation to Cargill producers also acknowledges this. The annual accumulation of P in pasture soils was estimated at 8 to 9 kg P/pasture acre per year. This was largely due to the application of excess poultry litter to pastures (CARTP016287-CARTP016290)."

(Expert Report, Ex.1 at 34-5, Appendix B, Ex. 2)

I declare under penalty of perjury, under the laws of the United States of America, that the foregoing is true and correct.

Executed on the 5th day of March, 2009.

Bernard Engel

Bernard Engel, Ph.D., P.E.

Poultry Waste Generation and Land Application in the Illinois River Watershed and Phosphorus Loads to the Illinois River Watershed Streams and Rivers and Lake Tenkiller

Expert Report of Dr. B. Engel

For
State of Oklahoma
In Case No. 05-CU-329-GKF-SAJ

State of Oklahoma v. Tyson Foods, et al.
(In the United States District Court for the Northern District of Oklahoma)

Dr. B. Engel, P.E.
Professor of Agricultural and Biological Engineering

May 22, 2008

Bernard Engel, Ph.D., P.E.

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7.2 P Mass Balance Literature

The scientific literature describes similar approaches as that used by the mass balance analysis set forth in Appendix B. In addition, some of these studies include portions of the IRW and reached similar conclusions as those highlighted above and in Appendix B.

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Nelson found nearly 6,000,000 lbs of P annually were applied to the landscape in the Arkansas portion of the Illinois River Watershed (7,000,000 lbs if cattle are considered but Nelson et al. acknowledge that cattle are recycling P). Nearly 5,000,000 lbs of P were estimated to be from poultry litter application to pastures in the watershed. This represents approximately 83% of P inputs to the watershed annually.

Sharpley et al. (2007) conclude that "the capacity of watersheds to assimilate nutrients, assuming some transport of manure from P-rich to P-deficient areas, should be determined and used in strategic planning of future development, expansion, or realignment of poultry operations."

7.3 Soil Test P Data for Illinois River Watershed

The soil test phosphorus data for the Illinois River Watershed area indicate soil P levels have been built to excessive levels well beyond agronomic requirements as a result of poultry litter application to pastures in most areas (Johnson, 2008). The soil test phosphorus levels within the IRW (Table 7.1) support the P accumulation described in the IRW mass balance. These high STP levels in the IRW contribute to P loads in IRW streams and rivers and to Lake Tenkiller.

Table 7.1. Soil Test Phosphorus Levels in the IRW Indicate Elevated P Levels Due to Poultry Waste Application

County	Soil Test P	Years
Benton	504	2000-2007
Washington	446	2000-2007
Adair	182	1995-2006
Cherokee	75	1995-2006
Delaware	160	1995-2006
Sequoyah	50	1995-2006

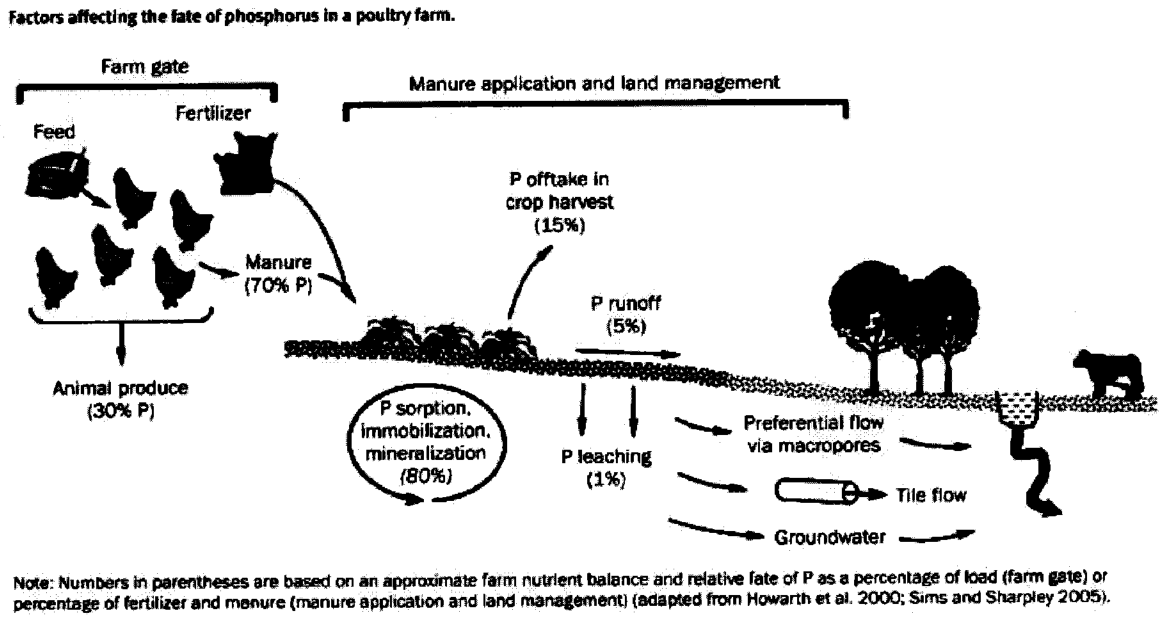

Figure 8.1. Factors affecting P loss on poultry farms (From Sharpley et al. (2007))

Elevated soil P from poultry waste application to pasture can also contribute substantially to P losses in runoff. Figures 8.2 and 8.3 show the results of a study in which poultry litter was applied to Bermuda grass plots (Sharpley et al., 2007). The soil P levels increased, resulting in greatly increased surface runoff of P, even 6 years after litter application was stopped. For high levels of STP, P loss with runoff may occur for decades and beyond as highlighted in Section 10 of this report.

Daniels et al. (1999) indicate that areas with high soil test phosphorus levels can have appreciable amounts of soluble phosphorus in runoff water and significantly impact water quality in receiving streams and lakes.

A powerpoint presentation for Cargill producers indicates that the long term effects of poultry waste land application should not be overlooked (CARTP016287-CARTP016290).

Surface soil (0 to 5 cm) Mehlich-3 P and mean annual dissolved P concentration of surface runoff and subsurface flow (70 cm depth) from bermudagrass before, during, and after poultry litter application (11 Mg ha⁻¹ yr⁻¹; 140 kg P ha⁻¹ yr⁻¹).

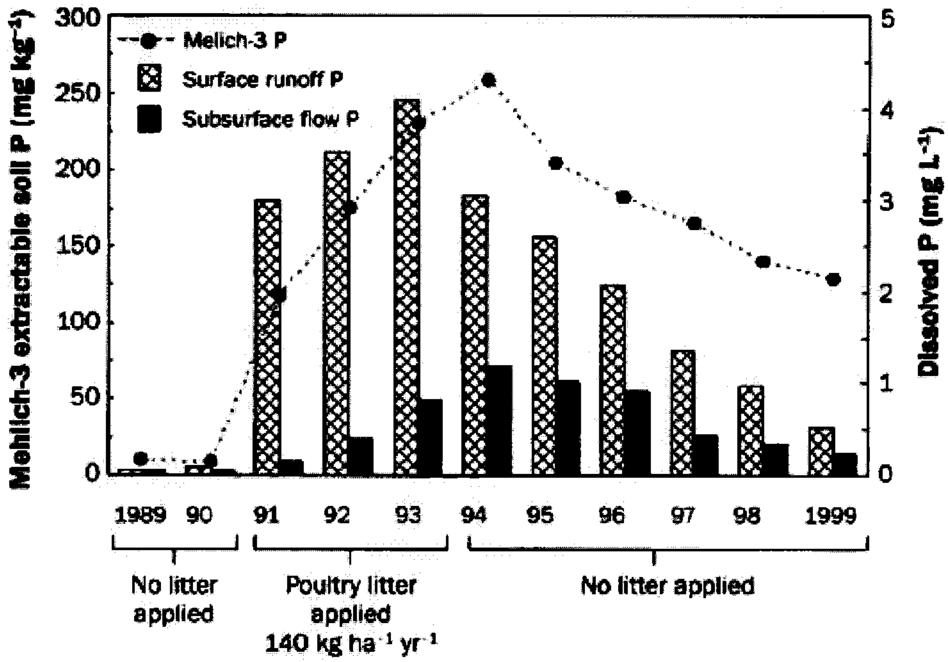

Figure 8.2. P Loads in Runoff Due to Elevated Soil P Levels (From Sharpley et al. (2007))

Phosphorus budget of poultry litter application, phosphorus uptake by bermudagrass, and total phosphorus loss in surface and subsurface flow from a Ruston fine sandy loam in Oklahoma.

Year	Litter P added (kg ha⁻¹ yr⁻¹)	Bermudagrass Yield (kg ha⁻¹ yr⁻¹)	Bermudagrass P uptake (kg ha⁻¹ yr⁻¹)	Total P loss in flow Surface (kg ha⁻¹ yr⁻¹)	Total P loss in flow Subsurface (kg ha⁻¹ yr⁻¹)	P balance
Before application						
1989	0	3,500	5.9	0.2	0.1	-6.2
1990	0	4,010	6.4	0.2	0.1	-6.7
During application						
1991	140	8,110	16.9	3.8	0.1	+119.2
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1999	0	6,900	17.4	0.9	0.2	-18.5
Total	420	76,060	179.0	32.9	3.8	+206.0

Notes: Balance of P was determined as litter P added − P uptake by grass +P loss in surface runoff + P loss in subsurface flow. Negative values indicate a net loss of P from the plots and positive values a net gain of P.

Figure 8.3. P Loads in Runoff Due to Elevated Soil P Levels (From Sharpley et al. (2007))

Appendix B

Illinois River Watershed Phosphorus Mass Balance Study

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Alexander
Consulting, Inc.

Illinois River Watershed Phosphorus Mass Balance Study

Prepared under the direction of:

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1.0 EXECUTIVE SUMMARY

A phosphorus mass balance study was performed on the Illinois River Watershed (IRW). The purpose of the study was to determine the source(s) of phosphorus causing eutrophication of Tenkiller Ferry Reservoir and water quality degradation of the Illinois River and its tributaries.

Based on the findings of the study, the following can be concluded:

1. Poultry production is currently responsible for more than 76% of the net annual phosphorus additions to the IRW.
2. Historical data indicates poultry production has been the major contributor of phosphorus to the watershed since 1964. Prior to 1964, dairy cattle were responsible for the majority of the phosphorus contribution.
3. From 1949 to 2002, there was more than 219,000 tons of phosphorus added to the IRW. Almost 68% of that addition, more than 148,000 tons, was attributable to poultry production.
4. Other contributing sources of phosphorus (net additions) include commercial fertilizers (7.5%), dairy cattle (5.2%), humans (3.2%), swine (2.9%), industrial sources – mostly poultry processing facilities (2.7%) and beef cattle (1.7%). The remaining sources of phosphorus evaluated in this study, which include urban runoff, golf courses, wholesale nurseries, and recreational users, are negligible (< 1%).
5. Of the three phosphorus exports from the watershed (harvested crops, harvested deer, and water leaving Lake Tenkiller through the spillway) outflow of phosphorus through the spillway at the south end of Lake Tenkiller was the largest. According to current estimates, the flow of water through the spillway removes just under 1.25% of the total annual phosphorus additions to the watershed. The remaining two phosphorus exports combined remove just over 0.25% of current annual phosphorus additions to the watershed, totaling a 1.5% removal of current phosphorus additions.

4.7 Summary of Findings

Figure 5 illustrates the current phosphorus additions and removals, in tons, to the Illinois River Watershed. This figure demonstrates there is more phosphorus coming into the IRW than is being removed, with poultry production being responsible for a large majority of the phosphorus addition (> 76%).

Figure 6 illustrates the current and historical phosphorus additions to and removals from the IRW. This figure demonstrates that for decades, the addition of phosphorus to the watershed has been greater than the removal of phosphorus. This results in an accumulation of phosphorus over time. It can be seen from this figure that poultry production has been by far the greatest contributor of phosphorus to the IRW since, at the very latest, 1964.

Figure 7 illustrates the current percentage of phosphorus additions to the IRW by source. This figure demonstrates that poultry, by far, is the major contributor of phosphorus to the watershed, being responsible for more than 76% of the current phosphorus additions.

Figure 8 illustrates the current and historical percentages of the phosphorus additions in the IRW attributable to poultry. This figure demonstrates a drastic increase in the percent of phosphorus addition due to poultry from 1949 to 1969, from 9% to 74 % From 1974 to 2002 there has been a steady increase in the percentage of the overall phosphorus addition in the IRW due to poultry, from 69% to 76%. Note that over the past three decades, poultry production has consistently been responsible for approximately 75% of the total annual phosphorus additions to the watershed.

Figure 9 illustrates a comparison of the current and historical percentages of phosphorus additions in the IRW attributable to poultry and the percentage attributable to all other sources combined (humans, swine, dairy cattle, beef cattle, commercial fertilizer, urban runoff, industrial sources, golf courses, wholesale nurseries, and recreational users). This figure demonstrates that the percentage of the overall phosphorus additions in the IRW due to poultry has been increasing over time while the percentage of overall phosphorus additions in the IRW due to all other sources has been decreasing over time.

5.0 CONCLUSIONS

Based on the findings of the study, the following can be concluded:

1. Poultry production is currently responsible for more than 76% of the net annual phosphorus additions to the Illinois River Watershed.
2. Historical data indicates poultry production has been the major contributor of phosphorus to the watershed since 1964. Prior to 1964, dairy cattle were responsible for the majority of the phosphorus contribution.
3. From 1949 to 2002, there was more than 219,000 tons of phosphorus added to the IRW. Almost 68% of that addition, more than 148,000 tons, was attributable to poultry production.
4. Other contributing sources of phosphorus (net additions) include commercial fertilizers (7.5%), dairy cattle (5.2%), humans (3.2%), swine (2.9%), industrial sources – mostly poultry processing facilities (2.7%), and beef cattle (1.7%). The remaining sources of phosphorus evaluated in this study, which include urban runoff, golf courses, wholesale nurseries, and recreational users, are negligible (< 1%).
5. Of the three phosphorus exports from the watershed (harvested crops, harvested deer, and water leaving Lake Tenkiller through the spillway) outflow of phosphorus through the spillway at the south end of Lake Tenkiller was the largest. According to current estimates, the flow of water through the spillway removes just under 1.25% of the total annual phosphorus additions to the watershed. The remaining two phosphorus exports combined remove just over 0.25% of current annual phosphorus additions to the watershed, totaling a 1.5% removal of current phosphorus additions.